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To: District Ranger, American River RD, Tahoe National Forest

Subject: Insect and Disease Evaluation of three stands in the Deadwood Project and one stand being considered for underburning (FHP Report #NE11-04)

On August 12, 2010 at the request of Kelly Pavlica, Silviculturist, American River RD, Danny Cluck, Forest Health Protection (FHP) Entomologist, and Bill Woodruff, FHP Plant Pathologist, evaluated three forest stands within the Deadwood Project area which Ms. Pavlica is considering for her silvicultural certification and one stand that the District is considering to underburn.. Ms. Pavlica and Kalie Crews, District NEPA Planner, accompanied us to the field. The objectives of this evaluation are to provide insect and disease information to assist in the selection of a suitable silvicultural certification stand, identify some of the forest health conditions within the Deadwood Project area, and discuss the influence these conditions would have on stand management objectives. Recommendations are provided where appropriate.

Sites evaluated within the Deadwood Project

(T14 and 15N; R11 and 12E, Mt. Diablo Meridian)

Site 1 – Stand #5

This mixed conifer stand (#5, from District records), adjacent to the Forest Hill Seed Orchard, contains much diversity in both species composition and stand structure. The overstory is stocked mostly with large ponderosa pine (*Pinus ponderosa*) with lesser numbers of white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*) and Douglas-fir (*Pseudotsuga menziesii*). The largest trees are approximately 36” dbh and 140’ in height. The understory is black oak (*Quercus kelloggii*), white fir, incense cedar, Douglas-fir and Pacific madrone (*Arbutus menziesii*). Old dead manzanita (*Arctostaphylos sp.)* “skeletons” are present on the forest floor. White fir dwarf mistletoe (*Arceuthobium abietinum f.sp. concolor)* is lightly infecting the overstory and understory white fir. Scattered large white fir snags are also present in parts of the stand.

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The mortality observed in the overstory indicates this stand may be overstocked. Understory vegetation was recently mechanically removed from some locations in Stand #5 but much of the stand is still overstocked. The overstocked areas could benefit by removing additional competing trees, mostly from the understory. During future thinning operations, dwarf mistletoe infected trees and those with other defects should be removed first, unless they are needed to achieve management objectives, such as providing wildlife habitat. Since no heterobasidion root disease was found, all freshly cut conifer stumps over 14" stump diameter should be treated with a registered borate compound to prevent infection by *Heterobasidion spp*., the cause of heterobasidion root disease. Spores landing on untreated stumps could infect healthy roots of surrounding trees; weakening and/or killing trees for decades. The best control for heterobasidion root disease is "prevention" which can easily be achieved by treating freshly cut stumps with a borate compound.

<u>Site 2 – Volcano Plantations</u>

We drove past some ponderosa pine plantations in the Deadwood Project area that were established after the Volcano Fire. Many of these plantations are overstocked with biomass and small sawtimber-size trees. These plantations were evaluated by FHP in 2010. Please refer to the FHP Report NE10-07, "Evaluation of western pine beetle activity in the Elliot Ranch plantation" for discussions and recommendations for ponderosa pine plantations in this area.

<u>Site 3 – Stand #52</u>

This stand (#52, from District records) is an 89% white fir stand (Fig. 1) that likely established over the last 100+ years in a brush field that was created by a stand replacing fire. Heterobasidion root disease caused by *Heterobasidion occidentale* (formerly, S-type *H. annosum*) is present in scattered locations in stand #52 (Fig. 2). Old and recent fir engraver beetle (*Scolytus ventralis*) caused mortality exists in much of the stand (Fig. 3). The presence of a few large rotting pine stumps near the ridge (Fig. 4) and a few large (22" to 52" dbh) ponderosa pine and sugar pine (*P. lambertiana*), mostly in the drainage indicates that pine is capable of growing in stand #52. A few incense cedar and black oak are present,

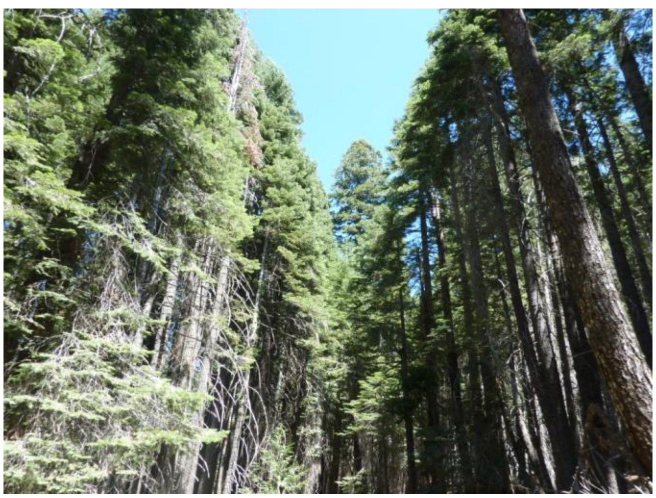

Figure 1. Heterobasidion opening surrounded by 100% white fir trees in the overstory with scattered large dbh white fir trees and a small incense cedar sapling in the understory.

Figure 2. *Heterobasidion occidentale* conk found in a decaying white fir stump.

Figure 3. Old fir engraver mortality.

as well as remnant brush species. The lack of species diversity, the presence of overstocked white fir impacted by heterobasidion root disease and the fir engraver, and the opportunity to replace diseased white fir with resistant pine and incense cedar provides a silvicultural challenge for managers.

Most of stand #52 is 100% white fir. The white fir have a quadratic mean diameter (QMD) of 14” dbh, however larger diameter (24” to 52”” dbh) white fir (Fig. 5) are scattered throughout but are mostly near the drainage. A few large sugar pine (QMD = 29” dbh) and ponderosa pine (QMD = 50” dbh) are also present, mostly near the drainage. The large trees present in the drainage demonstrate that the drainage may have provided refugia from historic stand replacing fires. Although the understory is composed mostly of white fir, a few incense cedars (mostly under 12” dbh) and pole-size sugar pine were observed. Black oak is present as small trees (QMD = 11” dbh) and sprouts in a few places. Cherry (*Prunus sp.*), whitethorn (*Ceanothus cordulatus*) and/or greenleaf manzanita (*Arctostaphylos patula*) are also present.

Figure 5. Very large white fir tree near drainage

Very light dwarf mistletoe infections were observed on a few white fir trees. White pine blister rust (*Cronartium ribicola*) was observed as upper branch flagging on a pole-size sugar pine. A few small brooms caused by incense cedar rust (*Gymnosporangium libocedri*) were observed on an incense cedar. Heterobasidion root disease has created openings in the stand and judging by the brush, downed logs and lack of snags in these openings, the disease appears to have been present for decades (Fig. 6 and also Fig. 1).

Figure 6. Forest floor in *hetrobasidion* opening.

White fir mortality has increased over the past three years throughout northeastern California as a result of drier than normal conditions. For example, the Palmer Hydrological Drought Index (PHDI) for Sierra Cascade Division, which encompasses the Deadwood area, has registered moderate drought conditions each year for 2007 - 2009 (Table 1).

Table 1. Palmer Hydrological Drought Index (PHDI) 2007 - 2010,
Water Year (Oct-Sept), California Division 2 (Sierra Cascade)

YEAR	PHDI*
2007	-2.64
2008	-2.71
2009	-2.52
2010	0.14

*PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions.
Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

White fir succumbing to fir engraver attacks are typically predisposed by other factors that compromise their health and vigor. In the Deadwood Project area, high stand density in some stands, prolonged drought, and heterobasidion root disease are all contributing factors in declining tree health. White fir trees in stand #52 will remain susceptible to high levels of mortality until the current drought conditions subside. More top kill and additional whole tree mortality should be expected next summer due to fir engraver beetle attacks sustained in 2010. If the Deadwood Project area receives adequate winter and spring precipitation in 2011, some white fir may be able to replenish their defense systems and resist further attacks. Some trees will require more than one season with adequate moisture before they will fully recuperate their natural defenses, assuming they are free of disease.

The average basal area of stand #52 is 413 ft^2/ac. and the stand density index (SDI) is 659. Current white fir mortality in stand #52 comprises 5% of the trees and 7% of the basal area. (Fig. 7). Most of the mortality appears to have occurred in the last decade. No pine, incense cedar or black oak mortality was recorded.

Figure 7. Recent fir engraver mortality.

Some of the observed mortality in stand #52 is caused by the interaction of heterobasidion root disease and the fir engraver beetle (also known as an insect and disease or pest "complex"), combined with the recent below average precipitation. Mortality caused by this pest complex is common in true fir stands throughout California. Any treatment which would result in establishing more pine and incense cedar in stand #52 would be desirable from a forest health prospective. This is because pine and incense cedar are resistant to *H. occidentale* and resilient to drought. If managers wish to control heterobasidion root disease in stand #52, two options can be considered:

1. Remove all white fir to achieve total control of *H. occidentale*, or
2. Remove only the white fir suspected of being infected to achieve partial control.

For option #1, total control of *Heterobasidion* can only be achieved by removing all host trees. In effect, all the white fir would be removed from stand #52 and kept from reestablishing for at least 30 years; which should be sufficient time for all the fir roots to completely decay; effectively killing all the *Heterobasidion*. In the place of white fir, non-host seedlings such as pine or incense cedar could be grown. Implementing option #1 would result in an even-aged stand with little structural diversity and no tree cover during the regeneration phase.

For option #2, all white fir would be removed from suspected *Heterobasidion* centers using group selection. Pine and incense cedar seedlings could then be planted in the resulting openings In the rest of the stand, the white fir would be thinned to a desired stocking by removing the slow-growing fir trees or clumps of trees and trees with unwanted defects. Slow-growing white fir trees are usually those with short leaders. A short leader can be caused by inter-tree competition (for soil moisture and sunlight), soil compaction, mechanical or weather-caused injury, and/or insect/disease injury (e.g. fir engraver, *H. occidentale*, dwarf mistletoe, etc.). Since it is impossible to know exactly which fir trees are infected with *H. occidentale*, option #2 will result in leaving some fir trees with non-symptomatic *H. occidentale* infections. Being a disease that infects primarily the heartwood in true fir, *Heterobasidion* infection in true fir is generally lethal only when an infected tree is stressed by drought and/or insects. In thinning stand #52, all pine and incense cedar and black oak could be retained to enhance heterogeneity. Sugar pine infected with white pine blister rust could also be retained, especially if the infections do not appear lethal to the tree. Implementing option #2 would result in much structural and species diversity in stand #52 and would maintain continual tree cover.

Increasing the percentage of pine and incense cedar in the stand will increase the stand resilience to drought and possibly future climate change. It is not recommended to treat the fir stumps with borate since the chemical only prevents infection in healthy fir stumps. Borates do not control *Heterobasidion* infections already residing in the roots (more about borates follows on the next page).

<u>Site 4 – Stand #57</u>

This stand (#57, from District records) is being considered for an underburn. Stand #57 is primarily widely spaced old growth sugar pine (30"+ dbh, 110'+ tall) and ponderosa or Jeffrey pine. One large sugar pine tree with red turpentine beetle (*Dendroctonus valens*) pitch tubes (Fig 8) on the bole appeared to be fading. Compaction from an old logging road a few feet from this dying tree may have stressed this tree by limiting the available soil moisture. No other tree mortality was observed. A dwarf mistletoe plant, *A. campylopodum*, was found growing on one 5-inch tall ponderosa pine seedling (Fig. 9)


Figure 8. Red turpentine beetle pitch tubes on sugar pine


Figure 9. Western dwarf mistletoe on 5" tall ponderosa pine

If prescribed fire is introduced into stand #57 to reduced fuels and manage stocking in the understory, unacceptable levels of mortality of old growth pine may result. This mortality most often occurs as a result of direct cambium or crown injury to individual trees during a fire. A mature sugar pine tree is especially susceptible to lethal basal cambium injury from the heat that develops when the deep duff and litter that has accumulated at its base is consumed. Deep duff and litter typically burns slowly and generates lethal temperatures, causing severe injury to the cambium; thus girdling the tree. To protect individual high-value large diameter pine from lethal cambium injury, raking the duff to mineral soil 24" from the bole before burning is recommended.

<u>Additional Discussion and Recommendations</u>

Stand #5 and the Volcano plantation stands may lack management complexity desired for silvicultural certification . On the other hand, stand #52 has insect and disease issues, it lacks heterogeneity, and it should be a good one for implementing the ideas from the US Forest Service Pacific Southwest Experiment Station General Technical Report 220: *An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests*.

Insect and disease caused fir mortality is occurring at elevated levels in Stand #52. Leaving this stand untreated would probably result in an elevated level of fir mortality continuing, especially during periods of below normal precipitation.

Any thinning alternative being considered for stand #52 should incorporate, where appropriate, past direction from the Regional Forester to thin to "ensure that density does not exceed an upper limit (for example: 90% of normal basal area, or 60% of maximum stand density index)" and to "design thinnings to ensure that this level will not be reached again for at least 20 years after thinning." (Regional Forester letter, "Conifer Forest Density Management for Multiple Objectives", July 14, 2004).

Planners could create variability in stand #52 by incorporating unthinned leave groups, by establishing pine and incense cedar in *Heterobasidion* openings, and by using structural thinning (as opposed to a strict thin from below or fixed-spacing thin). Drought tolerant species such as ponderosa and sugar pine, black oak and incense cedar could be retained over white fir to help increase their relative numbers within the stand to increase species diversity and provide resilience. Preference for removal should be given to diseased trees and trees infested with bark beetles, except where retention of these would conflict with management objectives. Structural thinning can be accomplished by removing all white fir from *Heterobasidion* centers; thus creating openings that would be planted with non-host species such as ponderosa pine, incense cedar and rust-resistant sugar pine.

Stump treatment with Borate: For all treatments on the Tahoe NF, it is recommended that a registered borate compound be applied to stumps of all freshly cut pine with stump diameters greater than14". The two borates registered for treating stumps in California are Sporax®, applied in granular form, and Cellu-Treat®, applied as a liquid. Treating true fir stumps over the entire Deadwood Project area with borate is not recommended because fir-type heterobasidion root disease is already present in much of the white fir. (Note: Stump treatment only prevents *H. occidentale* from infecting healthy roots; it does not cure the disease once it is present in the roots.) In situations where a stand of white fir trees appears healthy before treatment (i.e. the crowns are green and full, and the growth leaders are long), it is recommended to treat freshly cut stumps to prevent the pervasive fungal spores from infecting the stump and roots of healthy trees. Once *Heterobasidion* spp. becomes established in the roots of a true fir, it can continue to grow and spread to adjacent fir indefinitely, or until all the available wood in the fir roots and butts in and infection center is dead and decayed.

Climate Change: Predicted climate change is likely to impact trees growing in the Dogwood Project area over the next 100 years. Although no Tahoe National Forest specific climate change models are available at this time, there is a general consensus among California climate models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (C. Mallek and H. Safford, *A summary of current trends and probable future trends in climate and climate driven processes in the Eldorado and Tahoe National Forests and the neighboring Sierra Nevada, unpublished report, 2010*). The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431 or Bill Woodruff at 530-252-6680.

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Insect and Disease Information

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensively studied and has proven to be an important factor in the ecology and management of ponderosa pine throughout the range of this host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. The pitch tubes are red-brown masses of resin and boring dust. Relatively few, widely scattered, white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheromones released during a successful attack attract other western pine beetles. Attacking beetles may spill over into nearby apparently healthy trees and overwhelm them by sheer numbers.

Life Stages and Development

These beetles pass through the egg, larval, pupal and adult stages during a life-cycle that varies in length dependent primarily upon temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem and then mine into the middle bark where they complete most of their development. Bluestain fungi, introduced during successful attacks, contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions Affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the West since 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles. Information from surveys initiated in the 1930s indicates that there were enormous losses attributed to western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size through successive beetle generations as is typical with Jeffrey pine beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing outbreaks. When healthy trees undergo a sudden and severe moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant amounts of resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin flow to resist attack. Any condition that results in excessive demand for moisture, such as tree crowding, competing vegetation or protracted drought periods; or any condition that reduces that ability of the roots to supply water to the tree, such as mechanical damage, root disease, or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers and predaceous beetles are natural control agents when beetle populations are low.

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4” in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4” in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum,* into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by Cronartium ribicola an obligate parasite that attacks 5-needled pines and several species of Ribes spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes spp., its spread from Ribes spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.